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Avenues and Incentives for Commercial Use of a Low-Gravity Environment

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National Aeronautics
and Space Administration

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TECHNICAL PAPER

AVENUES AND INCENTIVES FOR COMMERCIAL USE OF A LOW-GRAVITY ENVIRONMENT

INTRODUCTION

The Space Act directs NASA to conduct its activities to preserve U.S. leadership in aeronautical and space sciences and technology and their applications. One of the unique and new technologies which have emerged from space effort is the processing of materials in an environment where the effective gravitational acceleration is very low (10^{-6} g to 10^{-2} g). This low-gravity (low-g) condition is often called microgravity, zero-g, or weightlessness. Because of its origin in and close ties to the space program, this emerging field is commonly referred to as materials processing in space (MPS). The usefulness of gravity levels above one-g has been recognized for many years. Separators, centrifugal casting operations, pumps, and a host of other equipment and industrial processes utilize "variable gravity" above one-g. Only in recent years, however, has much attention been given to "variable gravity" below one-g. Gravity levels below one-g can be achieved by placing an object in free-fall. For short-duration investigations of material properties and process mechanisms (a few seconds to a few minutes), a low-g or microgravity environment can be achieved by allowing specimens to free-fall in a drop tube or a drop tower, or by flying aircraft and rockets through carefully prescribed trajectories. A spacecraft in orbit about the Earth may be viewed as being in a state of continual free-fall. Thus, with the advent of the Space Shuttle in 1981, a low-g environment can be sustained for days at a time. By the end of the decade, free-flying spacecraft, which will be serviced by the Shuttle, will be routinely available. These "free flyers" will provide a microgravity environment for long periods of time (months to years). Available and planned NASA-owned facilities and flight systems which can provide a microgravity environment in the range of 10^{-6} g to 10^{-2}g, are shown in Figure 1.

INFLUENCE OF GRAVITY ON PROCESS MECHANISMS

From work done to date, it is clear that the microgravity environment opens a new frontier for material scientists and processors by providing new insights into the pervasive role of gravity on material properties and process mechanisms and by eliminating some of its disrupting influences that preclude some materials produced on Earth from achieving the theoretical performance characteristics of materials.

Convection

The elimination of gravity-driven convection in molten materials can preclude the sometimes undesirable stirring and mixing encountered during the growth of crystals, the casting or solidification of alloys and composites, chemical reactions, or the separation of biological materials (Figs. 2 and 3).

Sedimentation and Buoyancy

The elimination of gravity-induced sedimentation and buoyancy can broaden the spectrum of alloys and composites that may be formed by permitting particles of vastly different density to remain in suspension until solidification occurs. Also, the elimination of sedimentation and buoyancy eliminates the need for mechanical stirring. This is important in instances where the stirring may be detrimental to the materials involved (Fig. 4).

Gravity Induced Deformations

Where hydrostatic pressure controls or limits a process or the force of gravity (weight) causes deformation or fracture of a material, the elimination of gravity can provide opportunities for investigations of unique materials and manufacturing techniques (Fig. 5).

Containerless Processing

The elimination of the necessity to confine liquids and molten materials within a container can open interesting possibilities. Materials, depending upon their electromagnetic characteristics and the influences of processing in a gaseous environment, may be melted, mixed, manipulated, shaped, and solidified in free suspension by use of acoustic, electromagnetic, or electrostatic fields. Surface tension will hold the materials together in a mass. Another form of containerless processing which can be enhanced by microgravity is the float zone process; since the molten zone will be confined by surface tension, much more latitude may be available for crystal production in space (Fig. 6).

LAYING A SOUND FOUNDATION

The scientific and technological benefits which can be derived from the exploitation of materials processing in low-g (MPLG) are fundamental in nature and may result in significant improvements in material utilization and producibility; the potential economic benefits may be both substantive and viable. However, utilization of this technology must be approached with deliberation and realism.

Technology Base

In early work, there was considerable emphasis on investigating material processes in suborbital and orbital experiments that could rapidly lead to the production of commercially viable products in space. While a number of interesting results were obtained, it became clear that much more sophistication was required in process control and diagnostics, particularly with regard to the control and measurement of thermal gradients and quenching rates used in many of the processes. Sample preparation was found to be especially critical when it is necessary to control oxide formation or to completely homogenize a specimen. In containerless processing, much has been learned about the precise positioning and rotational control needed to prevent the sample from contacting the levitating device, as well as disruptive accelerations on and unwanted stirrings within the sample. Better methods for obtaining flow and temperature fields were found to be necessary in order to observe what is happening during a process. Present scientific and technological work sponsored by NASA is concentrating on identification of basic process mechanisms and gravitational influences on these mechanisms. Areas in which NASA-sponsored work is being carried out are shown in Figure 7.

Commercial Applications

A major difficulty that became apparent in attempting to develop commercial applications from initial experiments in microgravity was the identification of potential products. A number of studies have been carried out on the economic benefits of manufacturing specific items such as silicon ribbon, improved turbine blades, and various pharmaceuticals in space. Although such studies may have had some value in creating interest, stimulating ideas, and developing concepts, they ignored certain realities. It was tacitly assumed that space processing would result in a superior product and that improvements in certain Earth-based processes were limited irrevocably by gravitational effects. As it turns out, many of the identified improvements have been achieved by alternative techniques. In other cases, new technology has supplanted the need for the product. This will always be a problem with trying to identify specific needs for several years hence. Still, materials processing in microgravity can be used to obtain new insights into Earth processes, to make paradigms for comparison with materials made on Earth, and to make new and unique products. With regard to space-made products, present studies show that during the decade of the 1980's, they will likely be limited to low volume, high value items.

Understanding Commercial Needs

Social and economic benefits which may accrue from the emerging technology of MPLG will result from application of the technology to marketplace needs. NASA can make significant contributions to development of the technology base for MPLG. However, NASA has no direct involvement in the processing of materials for commercial markets. Thus, to ensure that the technology base which NASA develops is useful, careful analyses and close coordination between NASA and prospective users of the technology will be needed to ensure that the proper base is laid. To foster proper working relationships with prospective

users, the Commercial Applications Office, MPS Projects Office, at the Marshall Space Flight Center, has been created to work exclusively with commercial interests. This team forms a bridge between NASA and the commercial community, serving as a source of information and assistance for prospective users, as well as a focal point for commercial views and a channel by which these views can be articulated to NASA. This team also works to clarify NASA's policies regarding commercial rights in intellectual property, liabilities, equipment-leasing, and pricing. It is through this effort that NASA believes it can provide a simpler interface to the private sector, develop a better understanding of the incentives needed to elicit private initiatives and stimulate the inventive genius and entrepreneurial spirit in this country to utilize MPLG technology in beneficial ways.

INCENTIVES FOR COMMERCIALIZATION

To accelerate technological innovation based on MPLG technology and to provide incentives for commercialization, NASA has initiated a program wherein it will share in the cost and risk of early investigations and projects in the field of MPLG. In this regard, reference is made to the "Guidelines Regarding Joint Endeavors with Domestic Concerns" published in the "Federal Register," August 14, 1979, pages 47650 and 47651 (see Appendix). These guidelines indicate the basis on which NASA will share jointly with private concerns in the cost and risk of early MPLG investigations and projects.

Risk Sharing and Incentives

In these joint activities, NASA and interested, qualified commercial organizations enter into "constructive partnerships" as equals who have sufficient motivation toward common objectives to make independent commitments and to share in the risks and benefits. Activities are selected across the spectrum of materials processes to demonstrate that the low-g environment is a valuable tool for isolating and characterizing gravitational effects on ground-based material processes, or for actually producing unique materials in space for commercial application. Since market incentives are presently inadequate to bring about technological innovation based on low-g technology, under its joint activities program, NASA can provide certain tangible incentives such as: (1) providing flight time on the Space Transportation System (Space Shuttle) on appropriate terms and conditions, (2) providing technical advice, consultation, data; and use of facilities and equipment, and (3) entering into joint research and development programs where each party funds its own participation. Joint activities may range from exchanges of technical information and collaboration on low-g ground-based and flight experiments to joint projects (Joint Endeavors) to develop a marketable product.

Terms and Conditions

As stated in the "Guidelines" referenced above, the terms and conditions of joint efforts are negotiable; this includes such factors as the firm's right to proprietary data

and/or patent ownership, provisions for a form of exclusivity in special cases, and recoupment of NASA's contribution under appropriate circumstances. Until such time as normal market incentives provide a competitive and self-sustaining condition in the private sector for materials processing in low-g technology, the incentives and negotiability of terms and conditions will be used as a stimulus to encourage the more technologically advanced, entrepreneurally inclined firms to pursue applications of low-g technology.

Form of the Contract

Since NASA wishes to encourage the private sector in early commercialization efforts and since the regulations for Government procurements are not generally compatible with an entrepreneurial endeavor, NASA does not anticipate sponsorship of commercialization work through procurement type contracts. Rather, NASA is pioneering a concept of negotiating an agreement for joint investigations and joint projects with industry on a case-by-case basis. Thus, the agreement can be tailored to the specific needs of the parties for the specific investigation or project.

NASA/INDUSTRY WORKING RELATIONSHIPS

NASA has developed three basic levels of working relationships with private organizations. These provide the flexibility needed to meet a wide range of needs from large organizations with strong research departments to small entrepreneurial firms that want to develop a product for the market. They also provide for incremental increases in understanding and commitment by the parties. In all cases, the Government does not fund any of the work done by the firm, but rather each party funds its own activities separately.

Technical Exchanges

For companies interested in the application of low-g technology, but not ready to commit to a specific space flight experiment or venture, a Technical Exchange Agreement (TEA) has been developed. Under a TEA, NASA and a company agree to exchange technical information and to cooperate in ongoing ground-based research and analyses. In this way, a firm can become familiar with microgravity technology and its applicability to company needs at minimal expense. Under the TEA, the private company funds its own participation, and derives direct access to and results from NASA facilities and research, with NASA gaining the support and expertise of the industrial research capability. The first TEA was signed in June of 1981 with Deere and Company, Moline, Illinois, for work on the effects of gravity on solidification mechanisms and cast iron alloys. Several other companies are actively considering TEA's, including a metal producer, an equipment manufacturer and a chemical company.

Industrial Guest Investigators

Another joint activity is the Industrial Guest Investigator (IGI). The IGI arrangement is applicable to situations where NASA and an industrial firm share sufficient scientific interest such that the company appoints one of its scientists to collaborate, again at company expense, with a NASA-sponsored Principal Investigator on a space flight experiment. Once the parties agree to the contribution to be made to the objectives of the experiment, the IGI becomes a member of the investigation team, thus adding industrial expertise and insight to the experiment. The first IGI agreement was signed in May of 1980 with TRW Equipment Division in Cleveland, Ohio, for work on solidification experiments.

Joint Endeavors

Joint Endeavors provide a mechanism for NASA to share in the cost and risk of early space projects. The first Joint Endeavor Agreement between NASA and McDonnell Douglas Astronautics Company was signed in January 1980, and illustrates the key features of this third working relationship. McDonnell Douglas will use the Space Shuttle to develop and demonstrate the technology of continuous flow electrophoresis under low-gravity conditions and to ascertain the applicability of that technology to the production of pharmaceutical products. The agreement requires a substantial investment by McDonnell Douglas and its associates in each of three phases: (1) feasibility studies and planning, (2) flight experimentation and technology development, and (3) applications demonstrations. In return for McDonnell Douglas' promise to make results of the work available to the U.S. public on reasonable terms and conditions, NASA agrees to refrain from entering into similar joint endeavors or international cooperative agreements directly related to the development of commercial devices and processes which would compete with those resulting from the McDonnell Douglas endeavor. However, NASA is not precluded from selling flight time on the Shuttle to any other organization wanting to conduct the same or similar experiments. Significantly, NASA will not acquire rights in inventions made by McDonnell Douglas or its associates in the course of the joint endeavor unless McDonnell Douglas fails to exploit the inventions or terminates the agreement, or unless the NASA Administrator determines that an emergency exists. Additional joint endeavors are being pursued. For example, detailed discussions have been held with a small business firm regarding electroepitaxial growth of semiconductor crystals. Agreements with small business concerns require attention to means for minimizing financial risk and controlling negative cash flow. Joint Endeavor Agreements offer great prospects for commercial exploitation of MPLG technology.

PROGRESS AND CONCERNS

Work by NASA to build a broad technology base continues and significant progress is being made. Indications are that significant progress is also being made in removing or greatly mitigating many of the basic concerns and reservations which private organizations have about working with NASA on joint investigations and joint endeavor projects. Interest

in TEA's is steadily gaining momentum. Questions about intellectual property rights; the granting of process exclusivity as an incentive; working with interested parties one-on-one to determine if an idea and offer have merit; the ability/willingness of NASA to make a wide range of factors affecting the endeavor and its outcome subject to negotiations; keeping the formal agreement between the parties simple and flexible; and protection of proprietary data, have for the most part been satisfactorily answered in the view of many people in industry. Significant as this progress may be, there is still considerable hesitancy on the part of private organizations to seriously consider joint endeavor projects.

Discussions with commercial organizations and prospective investors reveal that several concerns and problems remain. To begin with, there is a shortage of ideas involving MPLG technology to meet marketplace needs. Because of its newness, not many people have done much thinking about the absence of gravity or the influence of gravity on their materials and processes. Also, it is obvious that there are risks which are not normally encountered in a high technology venture. Among them are the uncertainty of undertaking a venture in a field where the Government controls much of the capability to access the low-g environment; the relatively large amount of capital required to get through proof-of-concept (typically \$1.0 to \$10.0 million before tax write-offs) and the low salvage value if it is not successful; the relatively long time the money is at risk before the project generates a positive cash flow (typically 7 to 10 years); the increased risk from competitive technology and/or early product obsolescence due to the long time for development of products based on MPLG; and the added cost for access to the low-g environment, especially if space is required. Too, there is apprehension about the structure and operating flexibility of the Government, particularly with regard to its ability to function effectively in a dynamic joint venture, and about the possibility that the Government would impose constraints which would preclude a favorable return on investment. There is also concern about regulation, Government-sponsored competition or adverse legal or political action in later years if the venture is really successful. While these risks and uncertainties cannot be overlooked, NASA believes that satisfactory solutions can be worked out but that it can best be done in conjunction with private firms on a case-by-case basis. Certainly the door is open at NASA to try.

CONCLUSION

Although the field of MPLG is in its infancy, enough work has been done to show that the reduction or elimination of the pervasive influences of gravity on process mechanisms affords an opportunity for understanding and improving ground-based processing of materials, and for creating unique materials and products. The unique characteristics of microgravity and existing space technology combine to offer commercial organizations, and through them the public, potential significant benefits. It is not possible at this time to predict exactly what products will be produced or how they will be produced. This will be largely determined by the ingenuity of the people doing research on materials processing in low-g, the imagination of the entrepreneurs and the forces of economics. It is NASA's challenge to create the proper "climate" for this to occur by stimulating research on the ground to develop new ideas for flight experiments, by developing ground and flight hardware that is responsive to user needs in controls and diagnostics, by providing easy access

and multiple research and product development opportunities in a low-g environment for qualified individuals and firms, and by developing institutional arrangements, including patent and data protection, so that firms have a reasonable chance of return commensurate with their financial risk. NASA is presently working with commercial firms on a case-by-case basis to develop applications for this technology which will meet marketplace needs. While interest to date by private organizations has been limited, substantial progress is being made under NASA/Industry joint investigations and joint ventures to demonstrate the usefulness of low-g technology from both the technical and business standpoints. Thus, the field of materials processing in low-g may afford excellent opportunities for innovative individuals and organizations with scientific and engineering acumen.

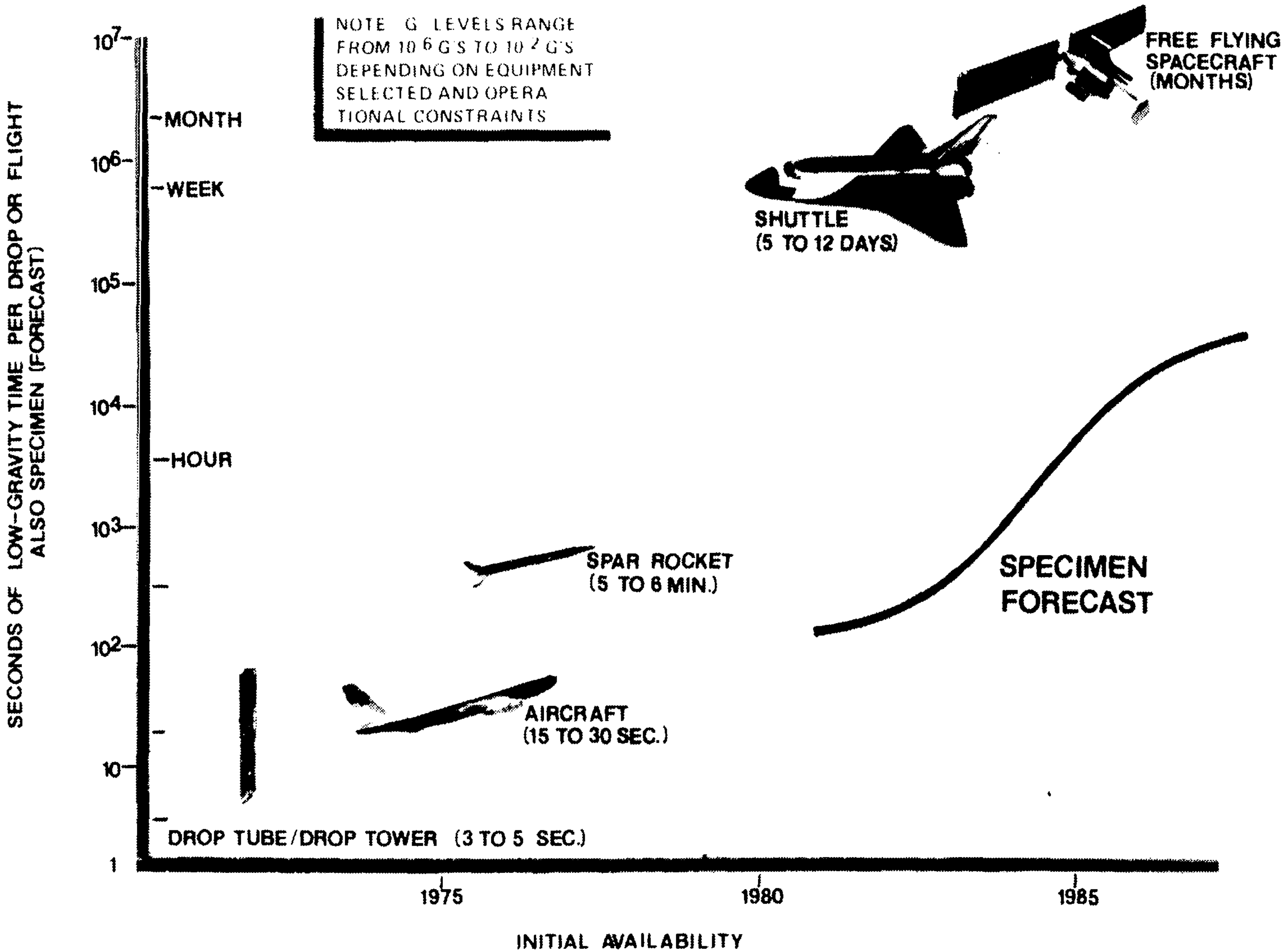


Figure 1. Low-gravity capability.

This microphotograph (at 350X) of a surface of a germanium crystal shows compositional striations due to convection in the melt when grown in one gravity. It was taken into space, partially melted and resolidified in low gravity. The more homogeneous composition due to the growth in the absence of convection can be seen.

The specimen lead shown at the right has a small amount of gold incorporated into one end to demonstrate the diffusion of gold into lead when melted. The micrograph taken of the sample melted in one gravity shows that convective flow has dispensed gold throughout the specimen. The picture taken of the sample melted in low gravity shows gold diffusion progressing through the sample. In microgravity, diffusion controlled processes, undisturbed by convection, are possible.

Crystals grown in one gravity often contain defects which effect mechanical and physical properties. Crystals grown in low gravity appear to have fewer dislocations as evidenced by sharper edges. The material shown is germanium-selenium (GeSe).

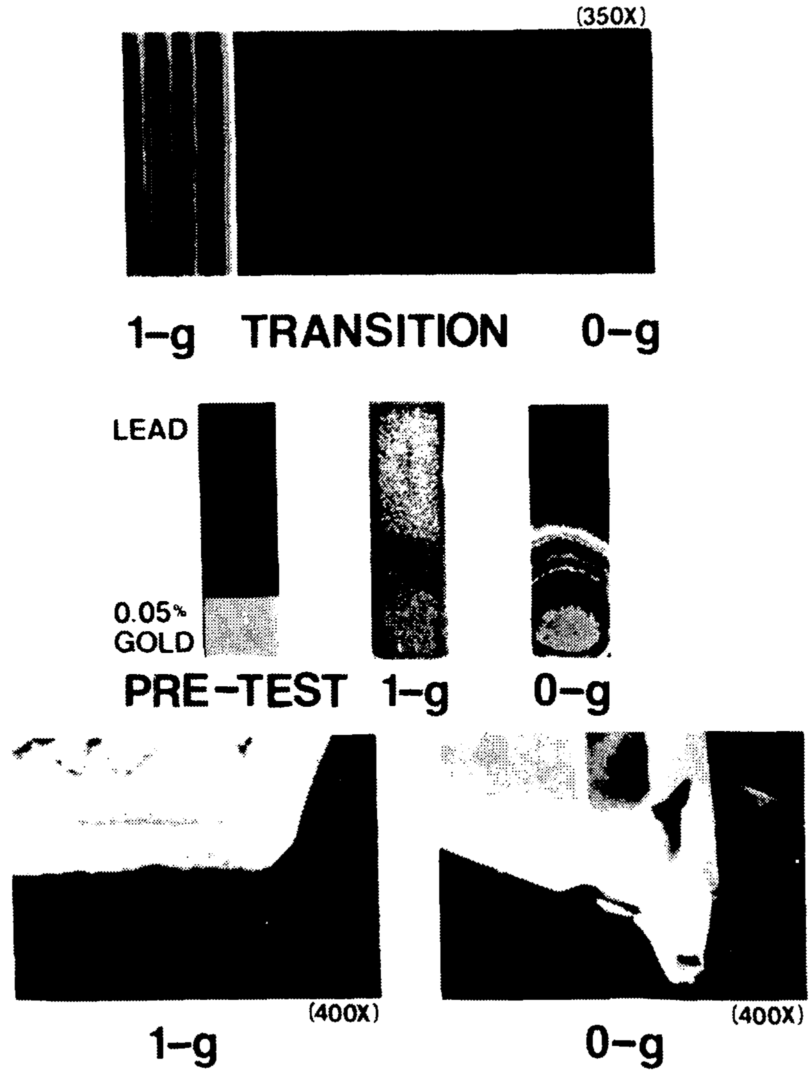


Figure 2. Convective effects.

A directionally solidified eutectic composition (natural two-phase solid which grows short fibers) can grow long, continuous fibers in the absence of convection at low gravity. Shown here is a demonstration of this phenomena, using sodium chloride-lithium-fluorine (NaCl-LiF)

In one gravity, convection causes the hot products of combustion to rise and new reactants to be supplied to the flame. In low gravity, a thin layer of flame can be initiated at the surface of the fuel where it contacts the oxidizer and can be carefully controlled, thus providing a unique opportunity to study combustion phenomena.

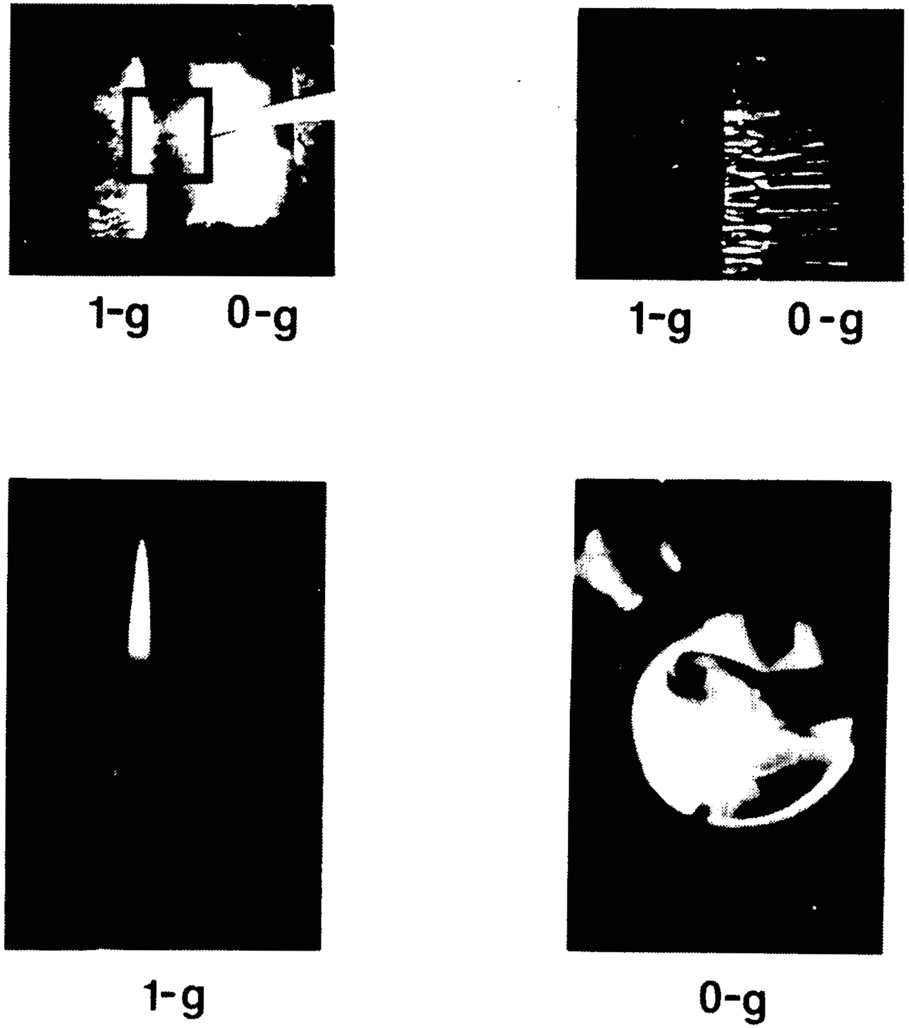


Figure 3. Convective effects.

A number of materials, such as immiscible semiconductors, segregate when solidified in one gravity. In low gravity, phase separation and segregation can be better controlled. This has been demonstrated, using aluminum-antimony (AlSb) as shown here.

Under one gravity conditions, low density materials will migrate toward the surface of a liquid (or melt). In low g, lighter density materials will remain in suspension for indefinite periods of time, thus removing a key constraint in the processing of composites and alloys where the constitutents have large density differences. Also, materials which must be stirred to remain in suspension in 1 g can be more effectively processed in low g.

In this solidification experiment, ammonium chloride (liquid is light and crystals are dark) was used to simulate a casting process. Under one gravity conditions, the dendrites formed and pieces broke off and settled to the bottom of the container, thus producing weaknesses in the sample. In low g, the dendrites formed, grew uniformly and did not break off. This resulted in significant improvements in the sample.

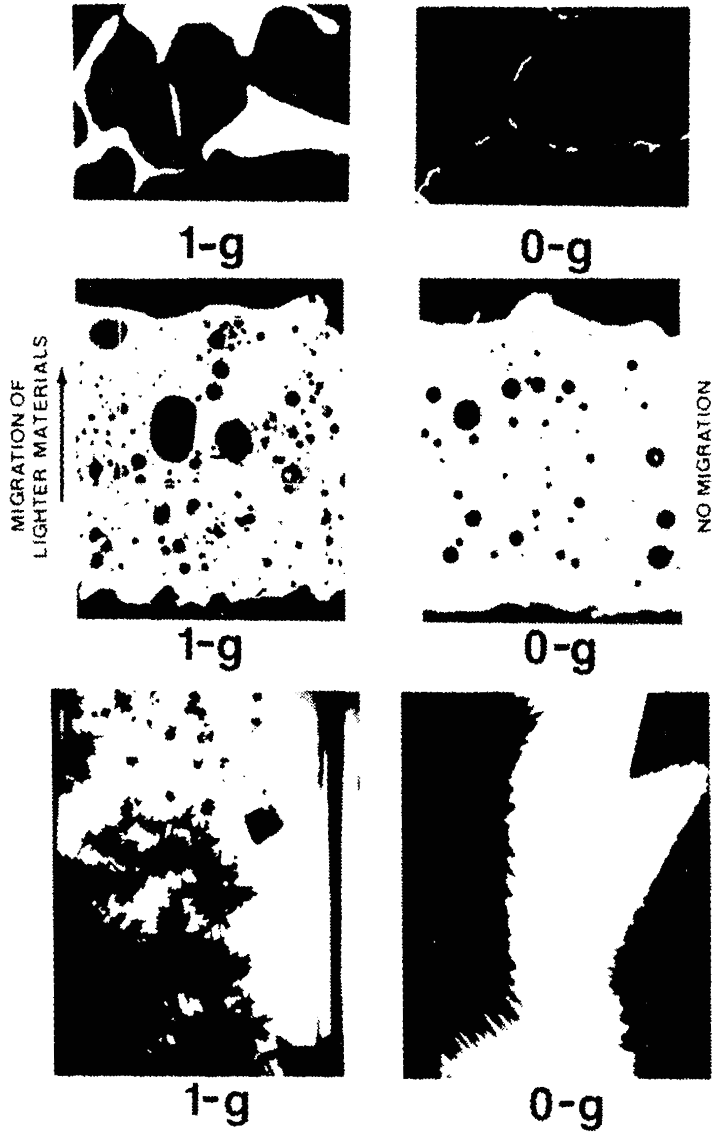
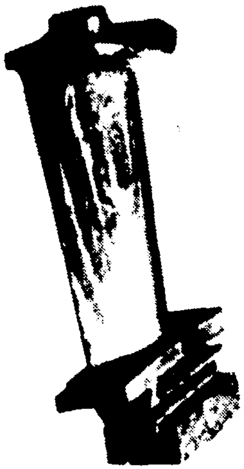


Figure 4. Sedimentation/buoyancy effects.

1-g

This highly purified single crystal deformed along the shear planes under its own weight during processing in one gravity. Large crystals which have weak internal bonding strengths can be made in microgravity without deformation and with fewer defects.

1-g

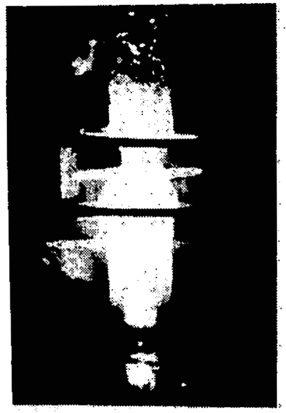


0-g

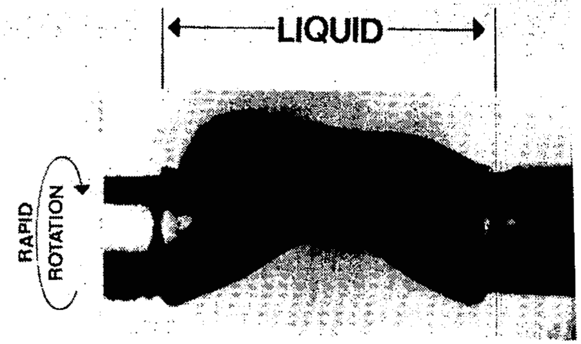
Finished machined parts can be melted and resolidified in space without significant deformation when contained only by a thin skin of ceramic material as shown in the photographs at the left.

Figure 5. Gravity induced deformations.

In the float zone process a bar of polycrystalline material is moved through the hot zone of a furnace in such a way that a thin molten zone moves along the bar and a single crystal is formed in the material solidified behind the zone. In low gravity, surface tension can hold a much larger molten zone in place, even if it is rotating rapidly as shown in the photograph at the far right.



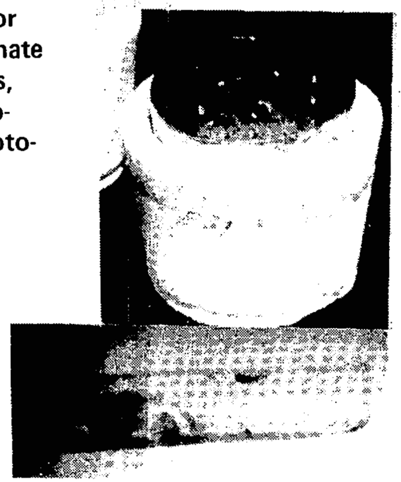
TYPICAL 1-g FLOAT ZONE PROCESS



SIMULATED FLOAT ZONE IN 0-g

Gravity necessitates containment of a liquid (or melt) in a crucible. The crucible can contaminate the melt or produce unwanted nucleation sites, resulting in undesirable optical or physical properties in the material as illustrated in the photograph at the right.

In microgravity, containerless processing can be done by using weak acoustic, electromagnetic or electrostatic fields to position, manipulate and form molten materials. The picture at the far right shows a hologram of acoustic standing waves containing a glass being melted without the use of a container.



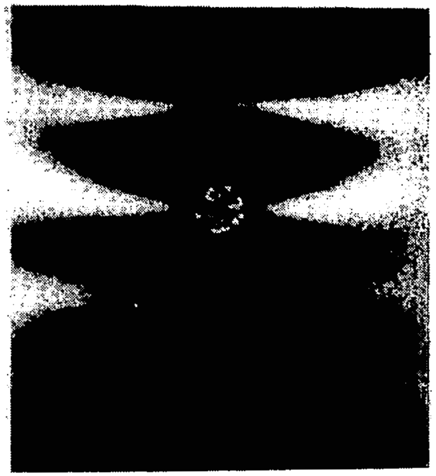


Figure 6. Containerless processing.

- CRYSTAL GROWTH AND SOLIDIFICATION
  - SOLID SOLUTION IR DETECTORS ($HgCdTe$, $PbSnTe$)
  - VAPOR GROWTH (HgI_2, ALLOY TYPE)
  - SOLUTION GROWTH (TGS, GROWTH ENVIRONMENT VS. MORPHOLOGY)
  - FLOAT ZONE (MARANGONI CONVECTION, RADIAL SEGREGATION, INTERFACIAL STABILITY)
- METALLURGICAL MATERIALS AND PROCESSES
  - IMMISCIBLE ALLOYS
  - MAGNETIC COMPOSITES
  - METAL FOAMS
  - HIGH G/R SOLIDIFICATION
  - SOLIDIFICATION AT EXTREME UNDERCOOLING
- COMPOSITES
  - CASTING OF DISPERSION STRENGTHENED ALLOYS
  - SOLID ELECTROLYTES WITH DISPERSED ALUMINA
  - PARTICLE PUSHING BY SOLIDIFICATION INTERFACES
- GLASSES
  - GLASS FINING
  - LASER HOST CLASSES
  - OPTICAL GLASSES WITH UNIQUE PROPERTIES
  - METAL GLASSES
- CHEMICAL PROCESSES
  - MONODISPERSE LATEXES (POLYSTYRENE MICROSPHERES)
  - STABILITY OF FOAMS AND SUSPENSIONS
  - COLLOIDAL INTERACTIONS
  - HIGH TEMPERATURE PROPERTIES OF REACTIVE MATERIALS
  - DIFFUSION CONTROLLED SYNTHESIS
- SEPARATION SCIENCES
  - HIGH VOLUME–HIGH RESOLUTION ELECTROPHORESIS CELL SEPARATION
  - PROTEIN PURIFICATION BY CONTINUOUS FLOW ISOELECTRIC FOCUSSING
- FLUID STUDIES
  - NON–BUOYANCY DRIVEN CONVECTIONS
  - WETTING AND SPREADING STUDIES
  - ROLE OF CONVECTION IN PROCESSES (ELECTROKINETIC SEPARATION, ELECTROPLATING, CORROSION, ETC.)

Figure 7. Materials processing in space program – current areas of research.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

[Notice No. 79-70]

Guidelines Regarding Joint Endeavors With U.S. Domestic Concerns In Materials Processing In Space

Background

NASA, by virtue of the National Aeronautics and Space Act of 1958, is directed to conduct its activities so as to contribute to the preservation of the role of the United States as a leader in aeronautical and space science and technology, and their applications. In furtherance of these objectives, the Administrator of NASA on June 25, 1979, promulgated a statement of *NASA Guidelines Regarding Early Usage of Space for Industrial Purposes.* These guidelines recognized that "since substantial portions of the U.S. technological base and motivation reside in the U.S. private sector, NASA will enter into transactions and take necessary and proper actions to achieve the objective of national technological superiority through joint action with United States domestic concerns."

Materials Processing in Space (MPS) is an emerging technology which can potentially provide public benefits through applications in the private sector. However, in the foreseeable future, normal market incentives appear to be inadequate to bring about technological innovation in the private sector based on this technology. Therefore, in accordance with the above referenced Guidelines, NASA contemplates entering into joint endeavors with U.S. industrial concerns. Through these joint endeavors, NASA seeks, within the context of the MPS program objectives, to broaden the base of understanding of MPS technology, particularly with regard to its usefulness in the private sector where economic benefits may result. Present MPS program objective are: a) to understand the pervasive role of gravity in materials processing; b) to develop and demonstrate enhanced control of materials processes in weightless environment; c) to explore the unique nature of space vacuum for materials processing; and, d) to foster commercial applications of MPS technology.

Nature of the Joint Endeavor

Joint endeavors in MPS will generally be for the purpose of: 1) engaging in research programs directed to the development and/or enhancement of U.S. commercial leadership in the field of materials processing in space, and 2) encouraging commercial applications of MPS technology. Joint endeavors may cover ground-based research to create a sound scientific basis for investigations in space; the investigation of materials properties or phenomena and process technology in the unique environment of space; the making in space of exemplary materials to serve as a point of reference for ground-based materials and processes; and the application investigations and feasibility demonstrations of space-made or space-derived materials and processes.

In joint endeavors, NASA and the industrial concern share in the cost and risks of the endeavor. Terms and conditions, including the business arrangements, are negotiable within the limits of prevailing statutes and regulations and will be commensurate with the risks, involvement and investment of all the parties. NASA's intent is to offer as much latitude as practical in joint endeavor arrangements. Due to the experimental nature of the program, both technically and institutionally, each endeavor will be negotiated on a case-by-case basis. Endeavors are expected to vary in size, complexity, and arrangements to

achieve diversity in the program. The number and/or size of the joint endeavors undertaken will depend upon the nature of the proposals received and resource availability. All joint endeavors will be subject to availability of appropriated funds, as well as NASA procedures regarding flight safety and verification.

NASA Provided Incentives

NASA incentives for these purposes may include in addition to making available the results of NASA research: (1) providing flight time on the space transportation system on appropriate terms and conditions as determined by the Administrator; (2) providing technical advice, consultation, data, equipment and facilities to participating organizations; and (3) entering into joint research and demonstration programs where each party funds its own participation.

Facts to be Considered in Establishing Endeavors

To qualify for joint sponsorship, the offeror must be engaged in business in the U.S. in such a manner that any promising results from the endeavor will contribute principally to the U.S. technological position; the proposed joint endeavor must comport with one or more of the MPS program objectives as stated above; and the technical uncertainties and risk involved must be significant enough to warrant the government's participation.

The factors to be considered by NASA prior to providing incentives may include, but not be limited to, some or all of the following considerations: (1) the public or social need for the expected technology development; (2) the contribution to be made to the maintenance of U.S. technological superiority; (3) possible benefits accruing to the public or the U.S. Government from sharing in results; (4) the enhanced economic exploitation of NASA capabilities such as the space transportation system; (5) the desirability of private sector involvement in NASA programs; (6) the merit of the research, development or application proposed; (7) the degree of risk and financial participation by the commercial concern; (8) the amount of proprietary data or background information to be furnished by the concern; (9) the rights in data to be granted the concern in consideration of its contribution; (10) the ability of the concern to project a potential market; (11) the willingness and ability of the concern to market and sell any resulting new or enhanced products on a reasonable basis; (12) the impact of NASA sponsorship on a given industry; (13) provision for a form of process exclusivity in special cases when needed to promote innovation; (14) recoupment of the NASA contribution under appropriate circumstances; and, (15) support of socioeconomic objectives of the Government.

Administration

The Associate Administrator, Space and Terrestrial Applications, is delegated the authority to enter into negotiations and to approve MPS joint endeavors on behalf of the Agency. Before proceeding into comprehensive evaluation of a joint endeavor, a preliminary assessment will be made of the merits of the offer. (Joint endeavor offers which are too sketchy or ill-defined to establish that the basic idea contained in the offer has merit, is in accord with MPS program objectives, or that the organization is willing to make significant contribution to the endeavor, will not be evaluated in depth and will be handled as correspondence or advertising.) This preliminary assessment will be reviewed by the Associate Administrator, Space and Terrestrial Applications, or his designee, to determine if the proposed endeavor warrants further consideration from NASA's standpoint. If this determination is positive, further evaluation will be made. After such evaluation and discussions with the offeror, if the parties mutually agree to proceed with a joint endeavor, designated representatives of NASA will enter into detailed discussions and negotiations with the offeror regarding the technical and business aspects of the offer in an effort to consummate a mutually satisfactory joint endeavor agreement. Management of the MPS joint endeavor program will be carried out by the Division of Materials Processing in Space of the Office of Space and Terrestrial Applications.

Due to resource limitations and necessity for diversity in the program, normally only one offer will be accepted to apply a particular materials process in a given technical area. If substantially similar offers are received within any 45-day period, they will be evaluated/negotiated together. The one which provides the best total consideration for the Government will be accepted. Special consideration shall be given to small and minority businesses, as appropriate.

August 3, 1979.

Robert A. Frosch,

Administrator.

[FR Doc. 79-24898 Filed 8-13-79; 8:45 am]
BILLING CODE 7510-01-M

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16. ABSTRACT

One of the unique and new technologies which have emerged from the space program is the processing of materials in a low-gravity (low-g) or microgravity (10^{-6} g to 10^{-2} g) environment. The reduction or elimination of the pervasive influences of gravity on process mechanisms affords opportunities for understanding and improving ground-based processes and for creating unique materials. The primary goal of NASA's present work in the field is to realize scientific and commercial utilization of the low-g environment for materials research and for process and product development. For the next several years, any products of commercial interest which necessitate processing in space will probably be low volume, high value items. To encourage the commercialization of materials processing in low-g, NASA, in parallel with establishing and demonstrating the scientific/technological precepts for analyzing and using a low-g environment, is establishing the legal and management mechanisms to share in the cost and risk of early commercial ventures, and is now working with commercial firms on a case-by-case basis to explore applications of this new technology to specific needs of the company.

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